By the KING's Patent.

A

TREATISE

UPON THE

DENDROMETER,

A

New-invented INSTRUMENT

FOR

The more certain and ready Meaſurement of Standing Timber, BY INSPECTION ONLY:

FOR

Facilitating the practical Operations of Engineering, Land-ſurveying, Levelling, Mineing, &c.

AND FOR

Performing mechanically the various Caſes of Plane Trigonometry, by a ſhort and familiar Proceſs, WITHOUT CALCULATION.

LONDON,

Printed for the PATENTEES:

And ſold by F. NEWBERY, in Ludgate-Street; J. BENNETT, Inſtrument-maker to their Royal Highneſſes the Duke of GLOCESTER and Duke of CUMBERLAND, in Crown-Court, Soho; B. COLE, Inſtrument-maker, in Fleet-Street; and T. WHITTELL, in Pater-noſter-Row.

By whom SUBSCRIPTIONS are received.

TO THE

RIGHT HONOURABLE

THE

EARL OF MORTON,

&c. &c. &c.

Preſident of the Royal Society, *&c.*

THIS

TREATISE

UPON THE

DENDROMETER

Is moſt humbly inſcribed,

By HIS LORDSHIP's much obliged,

and moſt devoted humble Servants,

Thomas Whittell,
John Duncombe.

TO THE

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President of the Royal Society, &c.

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and most devoted humble Servant,

Thomas Whitell,

John Duncombe.

PREFACE.

BEFORE *we enter upon the ſubject of the following ſheets, we cannot ſufficiently expreſs the grateful ſenſe we entertain of* His Majesty's *condeſcenſion, in being graciouſly pleaſed to permit us to exemplify the utility of our Inſtrument in* His Royal Presence.

We are highly obliged to the Right Honourable the Earl of Morton, *and the reſt of the members of the* Royal Society, *for the very candid and favourable reception, which the invention met with from that illuſtrious body.*

Our particular acknowledgments are due to the learned J. Bevis, M. D. *Mr.* Cowley, *Profeſſor of Mathematics at the* Royal Academy *at* Woolwich; *Mr.* Samuel Clark, *Teacher of the Mathematics in* London; *to Captain*

PREFACE.

Captain Cook, *Commander of the* Endeavour *ſloop of war (now upon a voyage to the* South-Seas *to obſerve the tranſit of* Venus) *and to ſundry other ingenious Gentlemen; by whoſe kind aſſiſtance we have been enabled to make divers improvements both in the Book and Inſtrument.*

We ſhould with pleaſure acknowledge the many perſonal civilities, which, in the courſe of our application, we have experienced from ſeveral of the Nobility and Gentry—eſpecially from two Noble Lords, and one Gentleman of diſtinguiſhed eminence in point of abilities and merit:—But as we are not at liberty to mention their names, we muſt leave them to the higheſt gratification of benevolent minds, the ſatisfaction reſulting from acts of goodneſs and generoſity.

Terms

Terms of Subſcription.

THE DENDROMETER (to be delivered with all poſſible expedition) completely finiſhed under the care of the INVENTOR, aſſiſted by Dr. BEVIS, &c. fitted to a proper theodolite, and contrived to act either ſeparately therefrom, or jointly therewith, with elegant mahogany-caſe, &c. - - - - - Twenty-five Guineas.

To Gentlemen already poſſeſſed of a theodolite, the DENDROMETER, completely made and fitted thereto, - - - - - - Ten Guineas.

The DENDROMETER alone, to act without a theodolite, for the uſe of meaſuring ſtanding trees, with proper ſtaff, caſe, &c.
Fifteen Guineas.

The expence of procuring the King's Patent, the making of the Inſtruments, and other incidents, being much greater than was, at firſt, apprehended—the Patentees are induced to hope that the Subſcribers will have no objection to depoſite Five Guineas in part of payment, upon receiving a receipt under the hands of perſons, properly authorized, that the ſame ſhall be allowed upon delivery of the Inſtrument.

That Meſſrs. F. NEWBERY, J. BENNETT, B. COLE, and T. WHITTELL, are properly authorized by the Patentees to receive the ſaid Five Guineas, and to give receipts for the ſame under their own hands, and NO ONE ELSE.

ADVERTISEMENT.

THE PATENTEES of the DENDROMETER take the Liberty to acquaint the Public, that His Majeſty has been graciouſly pleaſed to grant them his Royal LETTERS PATENT for a JACK, upon a Conſtruction ſingularly new and uſeful. It is ſo contrived, as to continue going for ſix Hours ſucceſſively, by a ſmall Weight, from the Height of ſix Feet only; and, when down, may be wound up with the greateſt Eaſe. It will turn a Joint of Meat of any Size, and is ſo certain in its Execution, as to require no Attendance. It is alſo calculated to ſhew the *Time, as a Clock*, while going. It is not apt to be out of Order, nor ſubject to the Expence and Trouble of Lines and Pullies; the many Difficulties of conveying them through different Rooms; the Danger of the ponderous Weight hanging to the Jacks in preſent Uſe; the frequent Neceſſity and vaſt Difficulty of winding them up; nor the continual Charges of a Smoke-Jack. The Price will be different, according to their Size and Finiſhing. The ſame, upon a more enlarged Plan, is intended to ſerve (inſtead of a Fire or other Engine) to raiſe Water out of Mines; whereby a prodigious Expence will be ſaved to the Proprietors thereof.

N. B. An Aſſortment will be finiſhed with as much Expedition as poſſible.

Any Perſons inclined to favour the PATENTEES with their Commands, are deſired to write (Poſt paid) to Mr. *Thomas Whittell*, in *Paternoſter-Row, London.*

INTRODUCTION.

INTRODUCTION.

IT is almoſt needleſs to mention, that the preſent method of meaſuring ſtanding timber is very defective, and erroneous; notwithſtanding the many attempts, which have been made, to render it eaſy and certain. There is *no* inſtrument, we apprehend, hitherto made public, which *can* give the meaſurement with any degree of preciſion. The quadrant, altho' of extenſive uſe and application, will by no means anſwer that particular purpoſe: for, if the tree ſhould either incline, or recline; or the ground, whence the obſervation is to be made, be irregular in the leaſt, the

meaſurement muſt be vague and erroneous. To prove the truth of this aſſertion, we ſhall take the liberty to quote the following general rules, for the uſe of that inſtrument, from the learned and ingenious Doctor * Harris: *viz.* "On the *quadrant* "you have a line called the *quadrat*, "which hath two ſides, divided each into "100 equal parts; and that on the left "hand is called *right ſhadow*, and that on "the right hand *contrary ſhadow*. By "which means 'tis very eaſy to take any "acceſſible altitude at one ſtation by the "*quadrant*. For, if the angle be juſt 45°, "the diſtance to the foot of the *object* from "the ſtation is equal to the altitude; but "if the angle be leſs than that, the "ſtring will fall on *right ſhadow* in the "*quadrat*. Then ſay, as 100 is to the "number of parts of the *right ſhadow*, cut "by the ſtring, ſo is the diſtance to the alti-"tude. So that if the ſtring cut 25, 75,

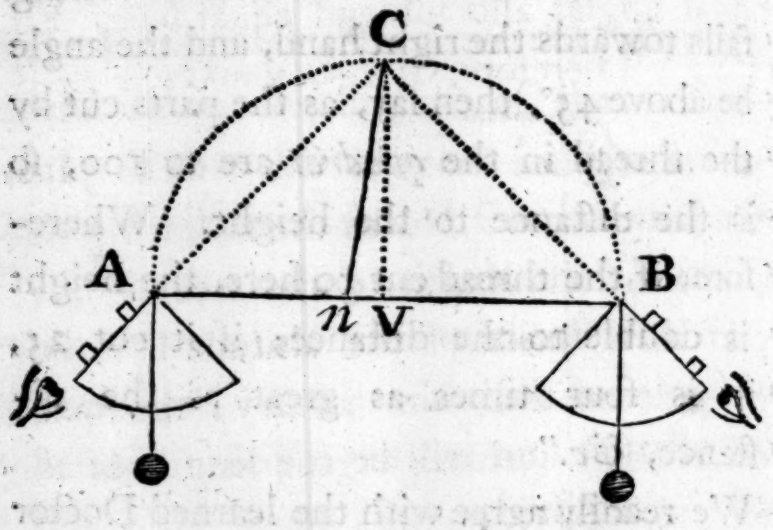
* Lexicon Technicum, Vol. I. Title *Altitudes*.

"or

" or 50, &c. the height is accordingly $\frac{1}{4}$, $\frac{3}{4}$,
" or $\frac{1}{2}$ the diſtance. But when the ſtring
" falls towards the right hand, and the angle
" be above 45°, then ſay, as the parts cut by
" the thread in the *quadrat* are to 100, ſo
" is the diſtance to the height. Where-
" fore, if the thread cut 50 here, the height
" is double to the diſtance; if it cut 25,
" it is four times as great as the di-
" ſtance, &c."

We readily agree with the learned Doctor in this reſpect, provided the object be perpendicular, and the ground horizontal: for altitudes of objects are always meaſured by the neareſt diſtances from their horizontal or level baſes. But, on the other hand, if either the object vary from a perpendicular poſition, or be ſituated on ſlanting ground, there muſt be an error; as may be proved thus:

Example I.



Let C*n* repreſent a tree ſtanding upon the horizontal baſe A*n*B, whoſe reclination *n*v from the perpendicular Cv being given: to find the length *n*C.

Make an obſervation at A, cauſing the plummet to hang directly over the 45th degree; then ſhould A*n* be equal to C*n* by the firſt general rule: But C*n* = A*n* + *n*v + C*n* − Cv; as is evident by the above figure.

Illustration.

Suppoſe A*n* = 20 F. and *n*v = 4 F. then is A*n* + *n*v = 24 F. Now, the angle at v being a right one, and the angle of obſervation at A being 45°, the angles ACv, CAv

CAv will be equal, Corol. 4. Eu. 32. 1. Equal angles alſo ſubtend equal ſides, Eu. 6. 1. Therefore, $An+nv=Cv=24$ F. Again, $\sqrt{\overline{Cv}^2+\overline{nv}^2}=Cn=24$ F. 3 I. ¼, &c. Eu. 47. 1. Hence the following rule for finding the length of the tree:

To the ſquare of the altitude C v, add the ſquare of the reclination n v; the ſquare root of that ſum will be the length of the tree C n required.

Example II.

Other things remaining as before, let B now be the place of obſervation, (the plummet ſtill cutting the 45th degree) and the horizontal line B v being equal to 24 F. To find the length of the tree C n.

Here B n ſhould be equal to C n by the firſt general rule: But $Cn=Bn-nv+Cn-Cv$; as by the above figure.

Illustration.

Now B n being equal to 28 F. and n v $=4$ F. then $Bn-nv=24$ F. The angle at v is a right one, and the angle of obſer-

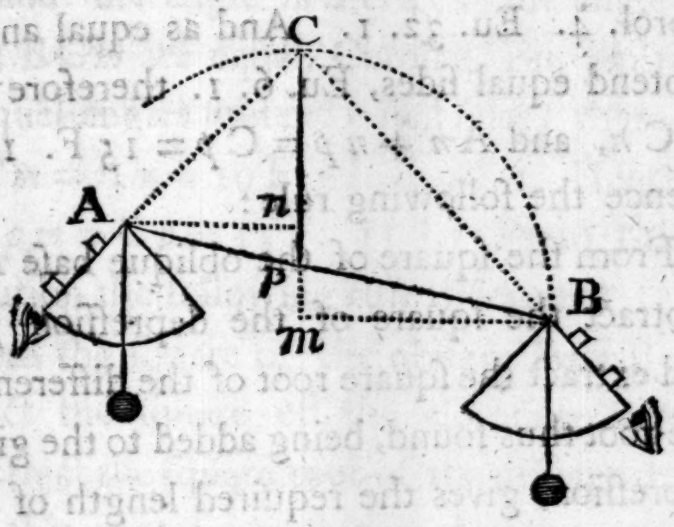
vation at B is 45°; therefore the angles v C B, C B v are equal, Corol. 4. Eu. 32. 1. Equal angles ſubtend equal ſides, Eu. 6. 1. Hence B n — n v = C v = 24 F. Again, $\sqrt{\overline{Cv}^2 + \overline{nv}^2} = Cn = 24$ F. 3 I. $\frac{3}{4}$, &c. Eu. 47. 1.

From this illuſtration it follows, that the ſquare root of the ſum of the ſquares of the altitude C v, and reclination v n, gives the length of the tree C n the ſame as before.

Having ſhewn the inutility of the quadrant when applied to meaſuring trees, in an oblique poſition, ſtanding on horizontal baſes; we ſhall next proceed to point out ſuch errors as will ariſe in the computation, when they are ſituated on aſcending or deſcending planes.

EXAMPLE

Example III.



Let C*p* repreſent a tree ſtanding perpendicular to the horizontal line A*n*, upon a deſcending plane A*p* B, whoſe depreſſion *p n* being given; to find the length of the ſaid tree. Make an obſervation at A, cauſing the plummet to hang directly over the 45th degree: then ſhould A*p* be equal to *p* C by the firſt general Rule: but C*p* = A*p* + *n p* — $\overline{\text{A}p - \text{A}n}$ by the figure.

Illustration.

Suppoſe A*p* equal to 14 F. and the depreſſion *n p* equal to 2 F. then $\sqrt{\overline{\text{A}p}^2 - \overline{np}^2}$ = A*n* = 13 F. 11 I. Eu. 47. 1. The angle

at n being a right one, and the angle nAC 45°, it follows, that ACn is alſo 45°, by Corol. 4. Eu. 32. 1. And as equal angles ſubtend equal ſides, Eu. 6. 1. therefore An = Cn, and An + np = Cp = 15 F. 11 I. Hence the following rule:

From the ſquare of the oblique baſe Ap, ſubtract the ſquare of the depreſſion pn, and extract the ſquare root of the difference; the root thus found, being added to the given depreſſion, gives the required length of the tree.

Example IV.

Cp repreſenting the tree, as before, let the obſervation be made at B, the plummet ſtill cutting the 45th degree of the quadrant, then ſhould Bp be equal to Cp, by the firſt general rule: but Cp = Bp — pm — $\overline{\text{B}p}$ — $\overline{\text{B}m}$, by the figure.

Illustration.

Let Bp be equal to 19 F. 5 I. and pm (the elevation of the aſcending plane BpA above the horizontal line Bm) equal to 3 F. 3 I. then $\sqrt{\overline{\text{B}p}^2 - \overline{pm}^2}$ = Bm = 19 F. 2 I.

Eu.

Eu. 47. 1. Now the angle C*m* B being 90°, and the angle *m* B C 45°, the angles *m* B C, B C *m* are equal, Corol. 4. Eu. 32. 1. But equal angles ſubtend equal ſides; therefore C *m* = B *m* = 19 F. 2 I. Eu. 6. 1. Hence B *m* − *p m* = C *p* = 15 F. 11 I. From this illuſtration the following rule is derived:

From the ſquare of the oblique baſe B *p* ſubtract the ſquare of the elevation *m p*, and extract the ſquare root of the difference; from this root ſubtract the elevation, and the remainder is the length of the tree.

Thus having ſhewn the inſufficiency of the quadrant, in meaſuring the length of trees not exactly perpendicular to the horizon, nor ſituated upon a level baſe; it ſeems altogether needleſs to add, that neither the theodolite, nor any other graduated inſtrument of the like nature, can give the true meaſurement of objects, ſuch as theſe, whoſe forms and ſituation are ſo extremely various and uncertain.

The author of this work having had frequent occaſion to obſerve the uncertainty of meaſuring ſtanding timber, unaſſiſted by

by any proper inſtrument for that purpoſe, conceived his preſent deſign of rendering the practice more certain and familiar, both to the owner and ſurveyor. In this purſuit many difficulties have occurred: how far he has obviated them, is humbly ſubmitted to the reader's determination.

The inſtrument now offered to the public, called a DENDROMETER,— for which His Majeſty has been pleaſed to grant His Royal Letters Patent,—is an invention entirely new. It is founded upon that branch of the mathematics called plane trigonometry, and its principles are chiefly derived from the 2d, 4th, 5th, 6th, and 33d propoſitions of the ſixth book of Euclid. It is formed to meaſure, with great accuracy, not only the length and diameter of any tree, in any ſituation, but alſo the length and diameter of the boughs, *by inſpection only*; and thence by the help of tables (hereunto annexed) the certain quantity of timber is obtained *without calculation or the uſe of the ſliding-rule*. By this means a criterion is fixed between the buyer and

ſeller

ſeller of an article, which becomes, every day, more and more valuable; as either party will have it eaſily in his power to prevent error, or to detect impoſition.

But, notwithſtanding the meaſuring of ſtanding trees with eaſe and certainty may be eſteemed no inconſiderable acquiſition; yet, we preſume, that this inſtrument, when fitted to a theodolite, will be found applicable to more extenſive and important purpoſes: *viz.*

For the practical meaſurement of the heights and diſtances of objects, acceſſible or inacceſſible, whether ſituated in planes parallel, or oblique, to the plane in which the inſtrument is placed.

For the taking of all angles, whether vertical, horizontal, or oblique, in any poſition of the planes in which they are formed; whereby the ſides and angles of all plane triangles, right-angled or oblique, are determined upon the inſtrument, *without any trigonometrical computations*, from the uſual *data*; *and that*, whether level to the line of ſtation, elevated above

or depreſſed below the ſame, acceſſible or inacceſſible, upon their own planes, and alſo upon the plane of the horizon.

From the above circumſtances, it need not be urged how uſeful it will be found in field-operations, particularly in the practice of engineering and land-ſurveying: For, by the method of applying the altimeter, elevation-index, and other moveable parts of the inſtrument, the meaſure of the required ſides and angles (right or oblique) is determined to ſufficient exactneſs *without any computation*; or the uſe of tables, hitherto neceſſary to aſſiſt the theodolite and all other graduated inſtruments.

In the practice of engineering, we apprehend, it will be found particularly uſeful; as not only the diſtance from any fortification, but alſo from any viſible part or projection thereof, together with the ſituation of the plane and place (with reſpect to the fortification) whereon a battery is proper to be raiſed, may all be readily obtained, without being under the neceſſity (according to the preſent mode of practice) of advancing

vancing upon the ſpot, or of approaching too near to the fire of the enemy.

We alſo conceive, it will be found exceedingly uſeful to a field officer under the following circumſtance. Suppoſe a body of the enemy are perceived, by the General, advancing on full ſpeed towards his army, and no time allowed for making variety of obſervations: by means of this inſtrument he can quickly diſcover (by lines drawn from the points of obſervation to the extremities of the rear of that body) the angles made, and thence the number of ſoldiers contained therein, which will enable him to direct, with very little trouble, what force to march againſt them.

Then its uſefulneſs in land-ſurveying, eſpecially on hilly or irregular ground, we apprehend, will be evident, when our readers are informed that the perpendicular riſe or fall of the land, the hypothenuſe, and baſe-line, neceſſary for protraction, are determined at once upon the inſtrument without

out calculation, *and conſequently without the riſk of error.*

In the courſe of this work, ſome things which were omitted, and others which appeared not ſufficiently clear to our judicious friends, are added by way of APPENDIX. But ſtill, if there ſhould remain any obſcure paſſages, we ſhall with pleaſure endeavour to elucidate them, at the requeſt of any perſon, who will give himſelf the trouble of pointing them out.

We ſhall now proceed to give a particular deſcription of the inſtrument, with plain directions for the uſe of it. The Tables * annexed are calculated to ſhew the whole quantity of timber contained in any tree, of any diameter, girth, and length, both by the exact and common method; by which means, the error in the uſual way of meaſuring round timber, ſo much to

* They are carried from 6 in. to 80 f. in length, and from 6 in. to 4 f. 3 in. $\frac{3}{4}$ in diameter, and are ſo contrived as to admit of being eaſily extended to any further dimenſions.

to the loſs of the ſeller *, is diſcovered and corrected.

To conclude, if, by this invention, the meaſurement of ſtanding trees be rendered eaſy and *certain*, and the practical operations of engineering, ſurveying, levelling, mining, *&c.* greatly facilitated, we flatter ourſelves it will meet with encouragement ſuitable to its merit and importance.

* It is obvious, that the preſent method of meaſuring timber is greatly to the diſadvantage of the ſeller: for, by taking the girth in the middle, and $\frac{1}{4}$ of the circumference in inches for the ſquare, the larger the tree, the greater muſt be the loſs of the ſeller, even to $\frac{1}{3}$ of the contents in a tree of 48 inches circumference.

DESCRIPTION

DESCRIPTION

OF THE

DENDROMETER.

THIS inſtrument (which gives a direct and general ſolution of the whole *thirteen caſes* in plane trigonometry, without calculation) is compoſed of divers members or parts, *viz.*

1. A *ſemi-circle* (A), which is divided into two equal parts or quadrants. The circumference of theſe quadrants are each divided into ninety degrees, *&c.* beginning at the middle of the ſemi-circle; and upon the *diameter* (B) thereof hangs a *plummet* (L),

(L), in order to fix the inſtrument in a vertical poſition; which may otherwiſe be effected by means of a ſpirit-level. There is alſo a *chord* (D) parallel to the diameter, and likewiſe a *radius* (E), which paſſes at right angles through the diameter and chord.

2. From a point on the radius hangs an *altimeter* (C), between the chord and diameter, to which is fixed a *ſmall ſemi-circle* (G), and a ſcrew to confine it in any poſition. The *altimeter*, which is contrived to form the ſame angle with the radius of the inſtrument as the tree forms with the horizon, is divided from its center both ways, each into forty equal parts; and theſe again, by ſmaller diviſions, into halves and quarters. Upon the *ſmall ſemi-circle* (G), on which is accounted the quantity of the angle made by the altimeter and radius, are expreſſed from 60 to 120 degrees, being 30 on each quadrant. The *radius* is numbered with the ſame ſcale of diviſions as the altimeter. There is alſo a *nonius* to the ſmall

ſemi-

ſemi-circle, which ſhews the quantity of an angle to every five minutes.

3. On the back of the inſtrument the *ſtock* (M) of the ſliding-piece is confined to the *axis* (N), which moves concentrically parallel to the *elevation-index* (F) on the oppoſite ſide, it being confined thereto. This *index* is numbered by a ſcale of equal diviſions with the altimeter and radius. At the end thereof is a *nonius*, by which the angles of elevation above, or depreſſion below, the horizon (meaſured upon the ſemi-circle of the inſtrument) are determined to every five minutes. There is alſo a groove in the radius, that ſlides acroſs the axis by means of a *ſcrew* (I), working between the chord and ſemi-circle of the inſtrument.

4. Upon the ſtock is a *ſliding-piece* (P), that always acts at right angles with the altimeter, by means of a groove in the latter. To the ſhank of the ſliding-piece is affixed a *moveable limb* (Q), which forms the ſame angle with the altimeter, as the

the bough forms with the body, or trunk, of the tree. This *limb* may be of any convenient length, divided into equal parts of the ſame ſcale with all the foregoing diviſions. At the extremity of the fixed axis, on a center, an *index* (R) with teleſcopic ſights works horizontally upon the moveable limb of the ſliding-piece.

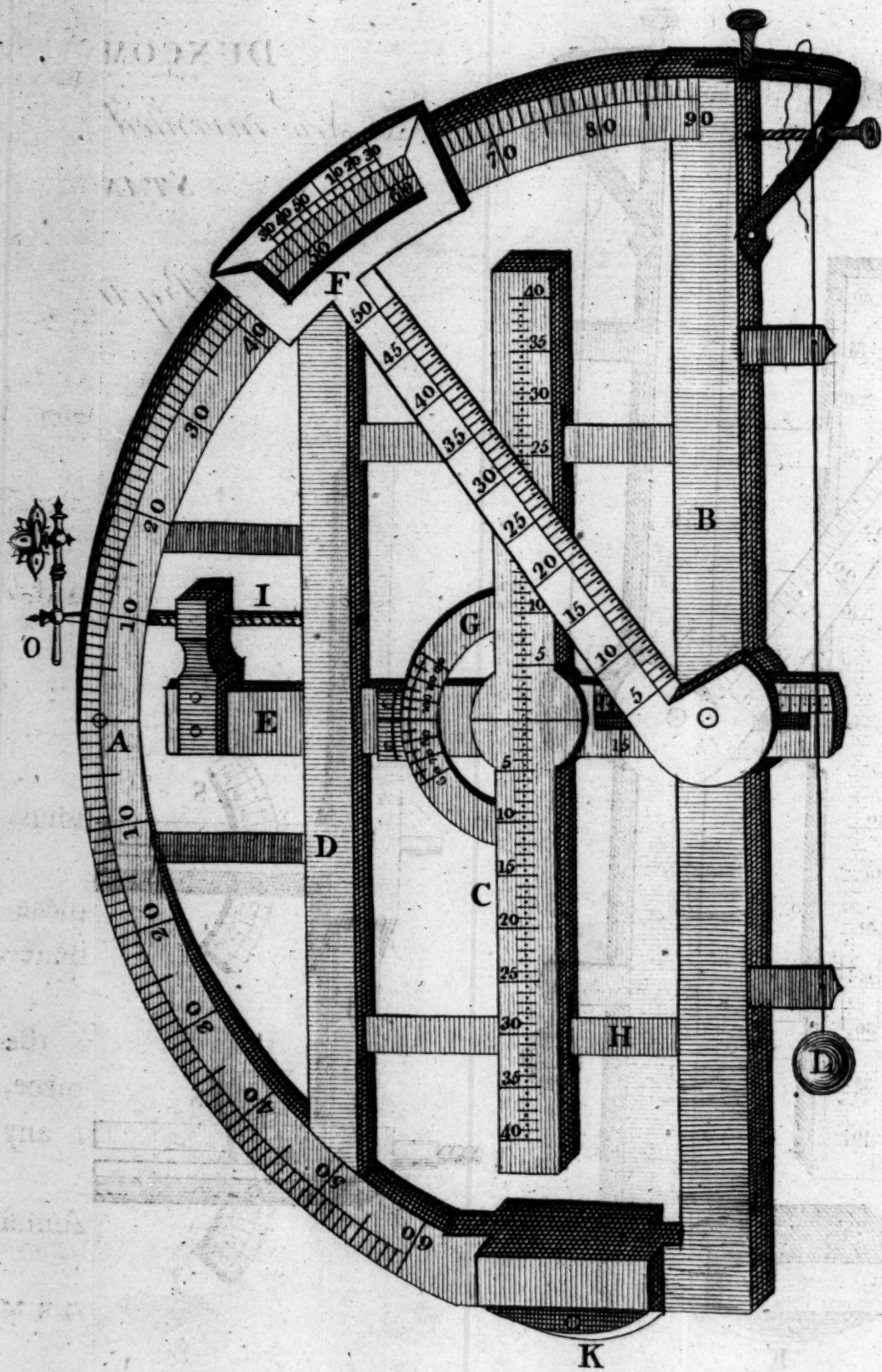
Upon this *horizontal index* (R) may be fixed a *ſmall quadrant* (T), (deſcribed with any convenient radius from the center whereon the index moves) divided into 90 degrees, beginning at a right line drawn from the center at right angles with the fiducial edge of the ſaid index; and upon the extremity of the axis a *nonius*, whereby to determine the quantity of an angle upon the quadrant to every five minutes. There are alſo two *ſmall circular arches* (S), ſerving to keep the ſights in a parallel poſition, each containing an equal number of degrees. Upon theſe *arches* is meaſured the angle, ſubtending a ſide equal to the difference of the altitudes of the obſerved

obſerved objects above the plane of the horizon, and whoſe baſe is the neareſt diſtance between the perpendiculars, in which the ſaid objects are ſituated.

N. B. The Dendrometer is fitted to a theodolite, and may be uſed either ſeparately therefrom or jointly therewith, as choice may direct, or occaſion require.

Reference *to the* Plate.

A The ſemi-circle.
B The diameter.
C The altimeter.
D The chord.
E The radius.
F The elevation-index.
G The ſmall ſemi-circle on the altimeter.
H Stays to the altimeter.
I The ſcrew, that draws the radius towards and from
K The ſtay, by which it is confined to the ſpring-ſocket or theodolite.
L The plummet.
M The ſtock of the ſliding-piece.
N The axis.
O The key to move the ſcrew of the radius.
P The ſliding-piece.
Q The moveable limb of the ſliding-piece.
R The horizontal index, on which the teleſcope is fixed.
S Small circular arches to confine the moveable limb of the ſliding-piece, and the horizontal index, in any poſition, *&c.*
T The ſmall quadrant upon the horizontal index.


A
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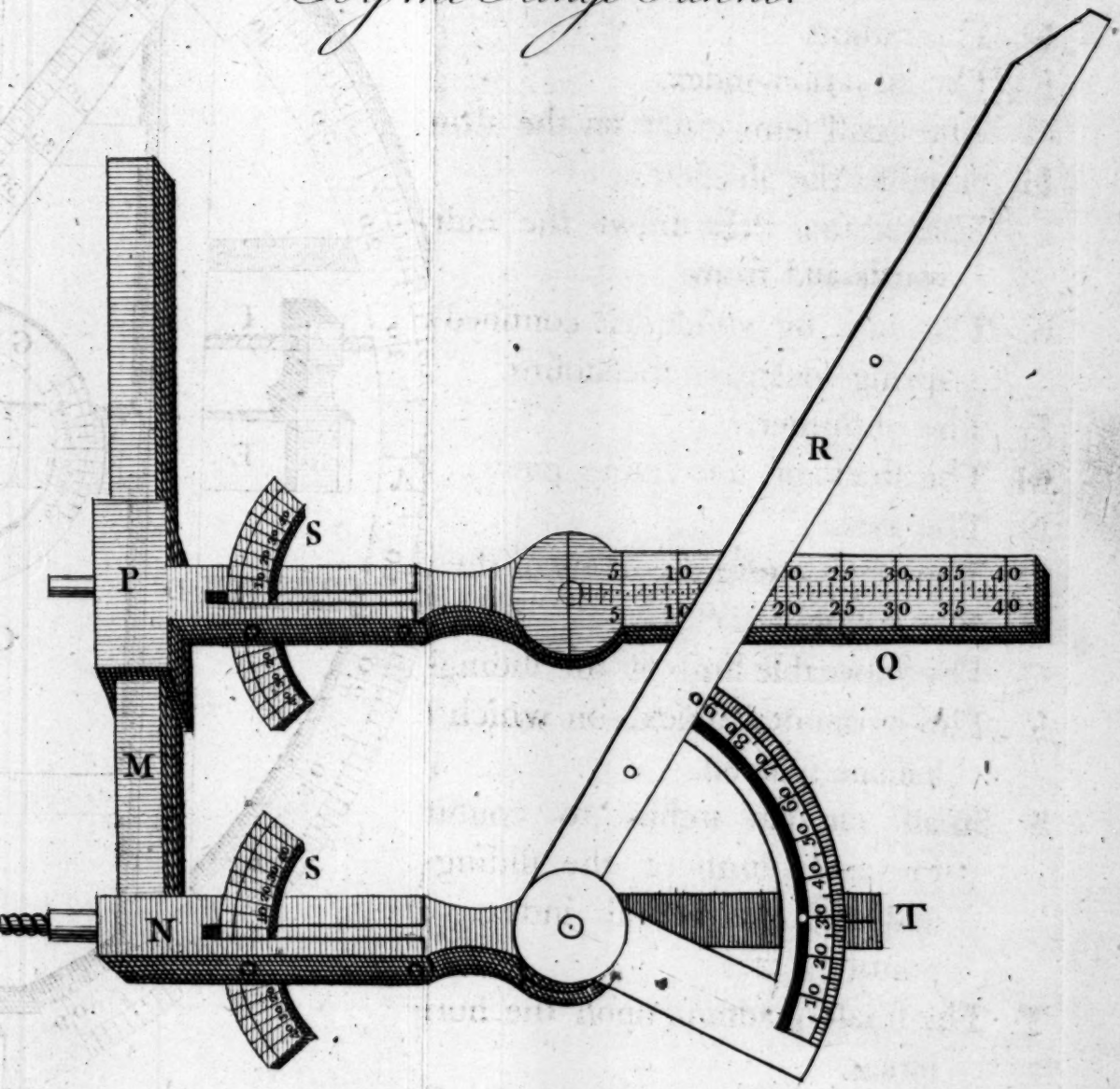
DUNCOMBE & WHITTELL'S

New-invented Instrument *for Measuring*

STANDING TIMBER

&c

By the King's Patent.



The FORM *of a* FIELD-BOOK *for Standing Timber.*

Mark and Number.	Height.		Diam.		True Solidity.			Common Solidity.		
	F.	I.	F.	I.	T.	F.	I.	T.	F.	I.
A — 1	30	0	4	0	7	1	0	5	2	0
2	—	—	—	—	—	—	—	—	—	—
3	—	—	—	—	—	—	—	—	—	—
&c.	—	—	—	—	—	—	—	—	—	—
B — 1	—	—	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—	—	—	—
3	—	—	—	—	—	—	—	—	—	—
&c.	—	—	—	—	—	—	—	—	—	—
C — 1	—	—	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—	—	—	—
3	—	—	—	—	—	—	—	—	—	—
&c.	—	—	—	—	—	—	—	—	—	—

DIRECTIONS

For the USE of the

INSTRUMENT.

CHAP. I.

To measure a tree in any position on level ground.

PLACE the instrument at any convenient distance from the tree; then, by means of the plummet, set it in a perpendicular position; which done, screw it fast upon the staff. Set the *altimeter* in the exact position of the tree *, and screw *it* fast. With your tape-line

* That is, if the tree recline or incline, so much must the *altimeter* recline or incline; or, if the tree be perpendicular, the *altimeter* must also be perpendicular.

measure

meaſure the horizontal diſtance from the tree to the *axis* of the inſtrument, and with your *key** move the *radius*, until *that* diſtance be cut upon it by the inſide of the *diameter*. Thus is your inſtrument properly rectified †.

To take the length of a tree.

Put your left hand upon the end of the *elevation-index*, and your right upon the ſhank of the ſliding-piece cloſe to the *ſtock*, on the under ſide; then move the *index* downwards, until you ſee, through the ſights, the bottom of the tree cut by the *horizontal wires*; and there note the feet and inches marked by the *index* upon the *altimeter* below the point of ſight or horizontal line. Move the *index* upwards, until you ſee the part ‖ to which you would meaſure, cut likewiſe by the *horizontal wires*; and there note alſo the feet and inches marked by the *index* upon the *alti-*

* In the form of a watch-key for that purpoſe.

† The inſtrument is to be rectified thus in all caſes.

‖ As far as the timber extends.

meter, above the point of ſight: theſe two quantities added together, give the exact length of the tree; which inſert in the ſecond column of your field-book, and then proceed

To take the girth.

With your tape-line meaſure the circumference of the tree in that part whence you took your horizontal diſtance; and let the diſtance on the *radius*, which was before cut by the inſide of the *diameter*, be now increaſed by one ſixth of the above-mentioned circumference ‖: this done, lower the *elevation-index* to the part of the tree, where you purpoſe to take the diameter; and ſcrew it faſt. Set the moveable limb of the *ſliding-piece* quite ſtraight, and the edge of the *horizontal index* upon the firſt diviſion thereof. Turn the whole inſtrument about to the left hand, until you ſee, through the ſights, the left ſide of the tree

‖ As the tape-line cannot be applied to the center of the body of the tree; and as the diſtance of that point to the circumference is nearly one ſixth part thereof, the above allowance becomes neceſſary.

cut

cut exactly by the *perpendicular wires*: then (the *inſtrument* being fixed) move the ſights only upon the *ſliding-piece*, until you ſee the right ſide of the tree cut alſo by the *perpendicular wires*; and you will find the true diameter marked by the *horizontal index* upon the *ſliding-piece*. Having entered this in the third column of your field-book, you may proceed

To meaſure the boughs.

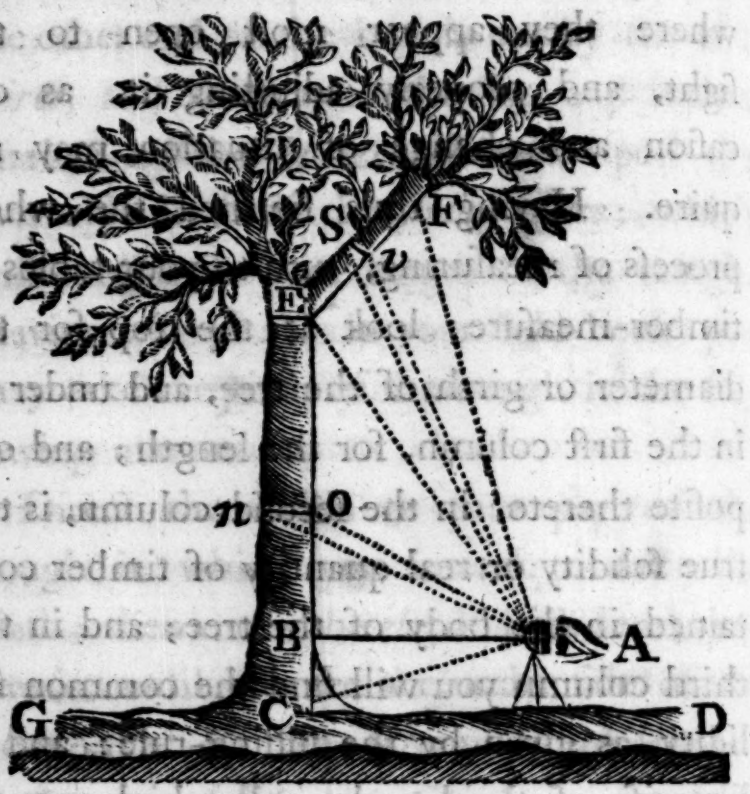
As the *radius* was increaſed by a ſixth, part of the circumference to take the diameter, it muſt now be reduced to its former quantity, *viz.* the diſtance from the tree to the *axis* of the inſtrument. This done, move the *elevation-index* upwards, until the bough becomes viſible through the ſights, and there ſcrew it faſt. Set the moveable part of the *ſliding-piece* in a poſition parallel to the bough, with the edge of the *horizontal index* placed upon the firſt diviſion thereof. Turn the whole inſtrument about, until you ſee, thro' the ſights, the ſhoot of the bough, cloſe to the

trunk of the tree, cut by the *perpendicular wires*: then move the ſights, until you ſee the other end of the bough cut by the ſaid *wires*, and there note the feet and inches marked by the *horizontal index* upon the moveable limb of the *ſliding-piece*; which will exhibit the true length of the bough. Having entered this in your field-book, you may take the girth of the bough in the following manner.

Direct the ſights to that part of the bough in which you intend to take the girth; then move the *elevation-index* downwards, until you ſee the under ſide of the bough cut by the *horizontal wires*; and there note the feet and inches marked by the ſaid *index* upon the *altimeter*; this done, move the *elevation-index* upwards, until you ſee the upper ſide of the bough cut by the *horizontal wires*; and there alſo note the feet and inches marked upon the *altimeter* as before: ſubtract the former quantity from the latter, and the remainder will be the true diameter of the bough; which enter in your field-book. In like manner

ner the reſt of the boughs are to be meaſured, obſerving to place the inſtrument where they appear moſt open to the ſight, and properly adjuſting it, as occaſion and change of ſituation may require. Having thus finiſhed the whole proceſs of meaſuring, turn to your tables of timber-meaſure: look at the top for the diameter or girth of the tree, and under it, in the firſt column, for the length; and oppoſite thereto, in the ſecond column, is the true ſolidity or real quantity of timber contained in the body of the tree; and in the third column you will find the common ſolidity, as given by the ſliding-rule: and ſo likewiſe of the boughs; all which may be transferred into your field-book at leiſure.

EXAMPLE I.



Let E B C repreſent a tree ſtanding upon the level ground G D. Place your inſtrument in a perpendicular poſition by the *plummet* at any convenient diſtance, as at A. Set the *altimeter* in the exact poſition of the tree. With your *tape-line* meaſure the diſtance from the tree to the center of the inſtrument, *viz.* B A (which we will ſuppoſe to be 17 feet). Move the *radius* either

either backwards or forwards, as there may be occaſion, until that number of feet be cut upon it by the inſide of the *diameter*.

Then direct the ſights to C by depreſſing the *elevation-index*, and there note the number cut by it upon the *altimeter* downwards from the center (ſuppoſe five feet); this done, elevate the ſights to the direction A E, and there alſo note the number cut upon the *altimeter* by the *elevation-index*, from the center upwards, which we here ſuppoſe 25 feet: add theſe two numbers together, and their ſum (30 feet) will be the whole length of the tree; which enter in the ſecond column of your field-book.

Next, with your *tape-line* meaſure the circumference or girth of the tree, in the place B whence you took your diſtance, and increaſe the number on the *radius* by one ſixth of that circumference: then depreſs the *elevation-index* to that part of the tree where you deſign to take the diameter, as at *n* o, and ſcrew it faſt: lay the moveable limb of the *ſliding-piece* quite ſtraight, and the

horizontal

horizontal index upon the firſt diviſion thereof: turn the whole inſtrument to the left, until, through the ſights, you ſee that ſide of the tree cut by the *perpendicular wires*: then move the ſights, until you ſee the other ſide of the tree cut in like manner by the *wires*; note the number cut by the *horizontal index* upon the moveable limb of the *ſliding-piece*, and you will find the true diameter of the tree *n* o, marked thereon, (ſuppoſe four feet,) which enter in the third column of your *field-book*.

The girth being thus obtained, move the *radius* back to the former diſtance, *viz.* 17 feet: then raiſe the *elevation-index* to the direction of the bough EF, which you deſign to meaſure, and there ſcrew it faſt: ſet the moveable limb of the *ſliding-piece* in a parallel poſition to the bough, and lay the *horizontal index* upon the firſt diviſion thereof. Now turn the whole inſtrument about, until, through the ſights, you obſerve the ſhoot of the bough at E, cut by the *perpendicular wires*: then move the ſights until you ſee the extremity

tremity of the bough, at F, cut alſo by the *perpendicular wires*; and there note the number marked by the *horizontal index* upon the moveable limb of the *ſliding-piece*, which determines the true length of the bough: this done, direct the ſights to that part, as S *v*, of the bough where you intend to meaſure the diameter; depreſs the *elevation-index*, until, through the ſights, you obſerve that point *v* in the under ſide of the bough which is cut by the *horizontal wires*; and there note the number marked upon the *altimeter* by the *elevation-index*; then raiſe the ſaid *index*, until, through the ſights, you ſee the upper ſide of the bough, at S, cut by the *horizontal wires*; there alſo note the number marked upon the *altimeter*: ſubtract the former number from the latter, and the remainder will be the diameter of the bough: then refer to your tables, as before-mentioned, for the ſolid content.

With regard to the uſe of this inſtrument, it being neceſſary in all caſes to adjuſt it according to the directions at the beginning of this chapter, and the whole fu-

ture

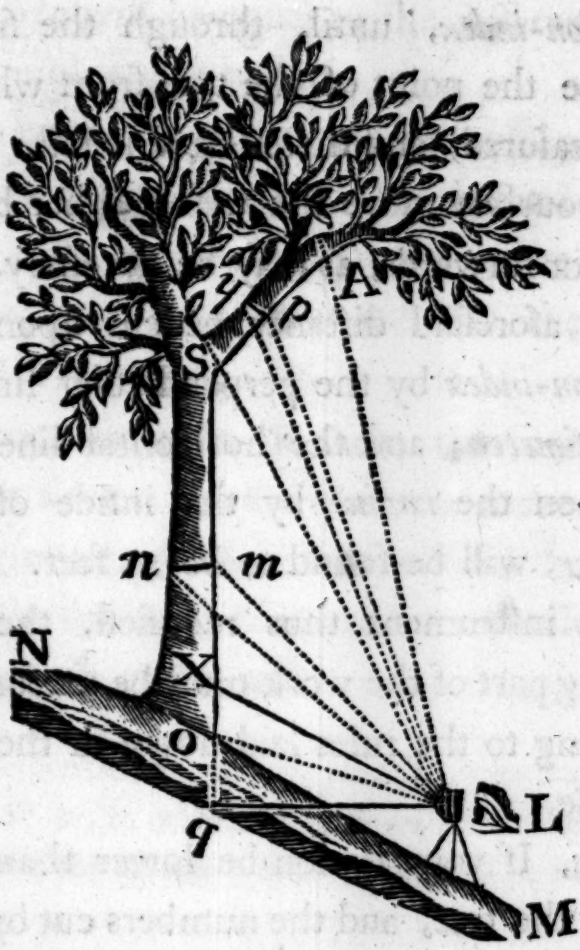
ture proceſs being nearly the ſame with the foregoing; we ſhall proceed to give ſuch examples, as may ſerve to obviate whatever difficulties are likely to occur, in finding the length of trees ſituated on ſlanting ground, crooked trees, *&c.* and likewiſe where they are inacceſſible by the intervention of a river, or other obſtacle.

CHAP.

CHAP. II.

To meaſure a tree in any poſition on ſlanting ground.

EXAMPLE II.



LET OXS repreſent a tree ſtanding upon the ſlanting baſe NM: place your inſtrument at any convenient diſtance, as at L, and there fix it perpendicular to the horizon;

horizon; ſet the *altimeter* in the exact poſition of the tree, and ſcrew it faſt. This done, meaſure the diſtance, X L, from the tree to the inſtrument with your *tape-line*, which we here ſuppoſe 24 feet: move the *elevation-index*, until, through the ſights, you ſee the point of the tree from whence you meaſured, and there ſcrew it faſt: then with your *key* move the *radius* either backwards or forwards, as may be neceſſary, until the aforeſaid diſtance be cut upon the *elevation-index* by the perpendicular line of the *altimeter*; and the horizontal line L *q*, cut upon the *radius* by the inſide of the *diameter*, will be found to be 19 feet.

The inſtrument thus rectified, the remaining part of the work muſt be performed according to the rules laid down in the firſt example.

Note, If your ſtation be lower than the root of the tree, and the numbers cut by the *elevation-index* upon the *altimeter* be, at the ſame time, *above the horizon* *, their difference

* By the horizon is meant that imaginary line, which paſſes through the ſights when the inſtrument ſtands

difference gives the true length of the tree. On the contrary, if your ſtation be higher than the top of the tree, and the numbers cut by the *elevation-index* upon the *altimeter* be *below the horizon*, the length of the tree will be equal to the difference of thoſe numbers, as before.

Moreover, if one number be found above, and the other below the horizontal line, drawn from the point of ſtation to the tree; in this caſe their ſum exhibits the true length of the tree.

If your ſituation be ſuch, that only *one* number be cut by the *elevation-index* upon the *altimeter*, (and it falls *either above or below* the horizon) *that number* expreſſes the exact length of the tree.

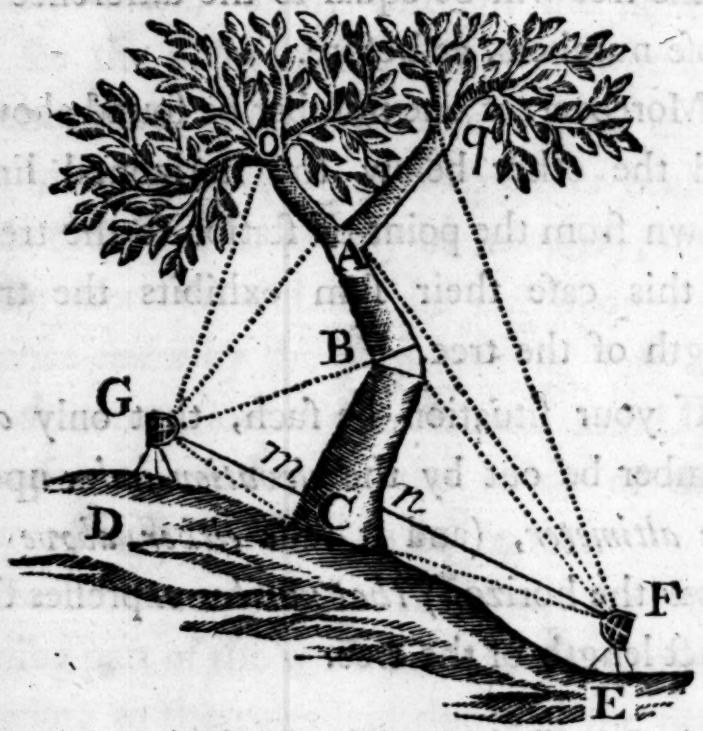
ſtands perpendicular, and the *elevation-index* points to *no degrees*: or, in other words, when it cuts the *center diviſion* on the *altimeter*, and lies parallel to the real horizon.

CHAP.

CHAP. III.

To meaſure an irregular tree, ſituated upon aſcending or deſcending ground.

EXAMPLE III.



LET ABC repreſent a tree ſtanding upon the ſlanting baſe DE: fix your inſtrument perpendicular to the horizon at a convenient diſtance FC, or GC, and ſet the *altimeter* in the exact poſition of the lower part (BC) of the tree; then with your tape-line meaſure the diſtance *n*F,

or

or *m* G, and proceed according to the rules laid down in the ſecond chapter.

This done, and the meaſurement of the lower part of the tree obtained, raiſe the *elevation-index*, until you ſee the point B *; ſcrew *it* faſt, and obſerve the number cut upon the ſaid *index* by the perpendicular line of the *altimeter*. Set the *altimeter* in the exact poſition of the upper part (A B) of the tree; ſcrew it faſt. Move the *radius* backwards or forwards, as occaſion may require, until the number before obſerved on the *elevation-index*, be again cut by the perpendicular line of the *altimeter*. Thus is your inſtrument rectified for the ſecond operation, which muſt be performed as follows.

Obſerve the number cut upon the *altimeter* by the *elevation-index*, when the ſights are directed to B; and alſo the number cut upon the *altimeter* by the ſaid *index*, when they are directed to A: the former of theſe numbers ſubtracted from

* The height to which you have already meaſured.

the latter, gives the length, A B, of the upper part of the tree. The diameter, and likewiſe the boughs, muſt be meaſured as before directed in the firſt example *.

CHAP.

* It muſt here be obſerved, that there will be a ſmall error in this meaſurement, from the circumſtance of the crooked part at B: for, if you meaſure on the exterior ſide of the crook (from F), then is the length, already taken, more than the *mean length*, by half the tangent of the angle of the tree's reclination from a right line. On the other hand, if you meaſure on the interior ſide of the crook (from G), then the length, already taken, will be leſs than the *mean length*, by half the tangent aforeſaid. Now this error, though very trifling, may be corrected, and the true meaſurement taken in the following manner; *viz.*

1. Meaſure the length of the tree, as before directed, both on the exterior and interior ſides of the crook; add them together, divide the ſum by two, and the quotient will be the *mean length* required. Or,

2. When the *altimeter* is ſet in the poſition of the ſecond part of the tree (A B), obſerve the angle of the tree's reclination or inclination upon the *ſmall ſemicircle* of the *altimeter*, and alſo meaſure the diameter of the tree in the crooked part. This done, ſet the *altimeter* in a perpendicular poſition, and the *elevation-index* to the angle of the tree's reclination or inclination,

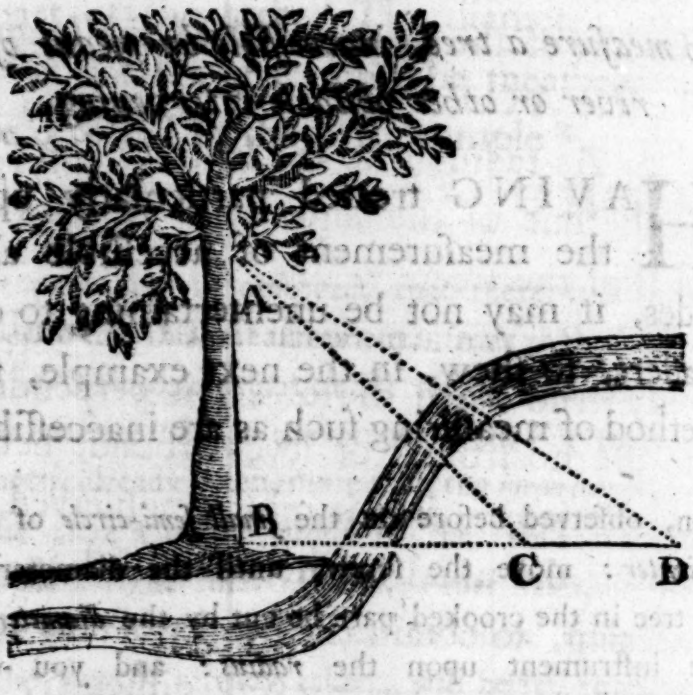
CHAP. IV.

To meaſure a tree, inacceſſible by means of a river or other obſtacle intervening.

HAVING treated particularly upon the meaſurement of acceſſible altitudes, it may not be unentertaining to our readers, to ſhew, in the next example, the method of meaſuring ſuch as are inacceſſible.

tion, obſerved before on the *ſmall ſemi-circle* of the *altimeter:* move the ſcrew, until the diameter of the tree in the crooked part be cut by the *diameter* of the inſtrument upon the *radius:* and you will find the *tangent* of the angle of the tree's reclination or inclination cut by the *elevation-index* upon the *altimeter.* Add half this tangent to the length of the tree, if on the interior ſide of the crook, and the ſum will be the *mean length* required. On the contrary, if on the exterior ſide of the crook, ſubtract half this tangent from the length of the tree, and the difference will be the *mean length* required.

Example IV.



Let A B repreſent a tree, rendered inacceſſible by the intervention of a river. Place your inſtrument at any convenient point, as at D, and take the angle B D A: enter it in your field-book. Advance to C, and there take the angle B C A; which alſo inſert in your field-book: meaſure the diſtance C D; and inſert it in your book: ſubtract the angle of altitude obſerved at D, from the angle at C, and the remainder will be the angle C A D: then the proportion will be,

1. As

1. As the ſine of the angle at A is to the diſtance C D between your ſtations; ſo is the ſine of the angle at D to the length of the line A C.

2. As radius is to the length of A C; ſo is the ſine of the angle at C to the height A B of the tree.

N. B. We are aware that this method is only true when the object is perpendicular to the horizontal or level ground, between the ſtations. But it muſt be obſerved, that this is the uſual method practiſed in engineering, to obtain the height of any fortification. To obviate every difficulty, when the ground between the ſtations is irregular, the inventor of *this* has conſtructed *another* inſtrument for the uſe of His Majeſty's engineers, which will readily determine, *without calculation*, the true height and diſtance of any tower or battery, or of any part thereof; and alſo its projection or depreſſion, either above or below the horizon.

CHAP. V.

Of land-ſurveying, &c.

HAVING already * mentioned the difficulties attending the ſurveying of hilly, or uneven ground, with the *theodolite*; and remarked that, amidſt ſuch a variety of calculations, ſurveyors may be liable to dangerous errors; we ſhall further beg leave to obſerve, that notwithſtanding Mr. HUME § (editor of *Wilſon's Surveying*) ſeems to reject the uſe of the *theodolite*, and other graduated inſtruments; yet we can by no means agree with that gentleman, in recommending the uſe of the *chain alone*, as fully ſufficient in *all* caſes. On the contrary, we poſitively affirm, that no eſtate or lordſhip can be correctly ſurveyed by the *chain alone*, unleſs the land be *truly level*. For in meaſuring over aſcents and deſcents, it is evident, the meaſurement of ſuch line will be much longer than the horizontal or baſe line; and,

* In the Introduction.

§ In his Argument, p. 291.

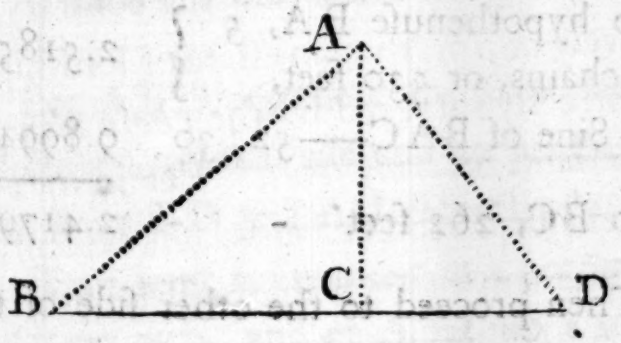
conſequently,

conſequently, no *true* plan can be formed, without the aſſiſtance of ſome graduated inſtrument, to take the angles of acclivity or declivity, previous to calculation.

We ſhall now proceed to illuſtrate by compariſon, in the following chapter, the advantage of this our inſtrument over the *theodolite*, &c. in the practice of ſurveying, particularly of hilly ground.

CHAP. VI.

The proceſs of ſurveying hilly ground with the theodolite, &c. *from* WILSON's Surveying, Sect. I. p. 146.



"LET the mountain BAD, be ſup-
" poſed to ſtand upon the horizontal
" line, or plane BCD, and its perpendicu-
" lar altitude AC, and the whole horizon-
" tal line of the plane BD is required.

" Bring the inſtrument to the bottom of " the mountain or hill at B, and let your " aſſiſtant go to the top of the hill at A, " and place a mark that may be ſeen from " B, and elevate your inſtrument, ſo that " you can, through the ſights, ſee the mark " at A, and obſerve the degree of altitude, " which ſuppoſe 37 deg. 30 min.

" The angle ABC, found as above, being " 37 deg. 30 min. the angle BAC is 52 " deg. 30 min. (by *Theor.* V. the angle " BCA being a right-angle:) therefore to " find the baſe BC, by *caſe the firſt* of right-" angled plane triangles,

" As radius - - -	10.00000
" To hypothenuſe BA, 5 " chains, or 330 feet,	2.51851
" So Sine of BAC——52 : 30	9.89946
" To BC, 262 feet - -	2.41797

" Then proceed to the other ſide of the " mountain or hill at D, and with your in-" ſtrument take the angle CDA, as before, " which ſuppoſe 56 deg. 00 min. and let the " ſide DA, when meaſured, be 270 feet, " from thence find the baſe CD, as before.

" The

" The angle D being 56 : 00, the angle " DAC will be 34 : 00 to find CD.

" As radius - - -	10.00000
" To AD——270 feet - -	2.43136
" So ſine of DAC 34 : 00 -	9.74756
" To CD——151 feet - -	2.17892
" The Line BC - - -	262 feet.
" Added to CD - - -	151 feet.
" The ſum is the whole line BD	413 feet.

N. B. Mr. WILSON has omitted the calculations for the perpendicular height.

The proceſs of ſurveying the ſame hilly ground with the new-invented inſtrument.

Let ABD repreſent the ſame mountain as before, whoſe baſe and perpendicular are the lines BD and AC reſpectively.

Place your inſtrument in a perpendicular poſition at B, and at A ſet up a mark, of equal height with your inſtrument. Raiſe the *elevation-index*, until you ſee the mark at A through the ſights, and there ſcrew it faſt;

faſt: then with your chain meaſure BA, the ſide of the hill, (which admit to be 20 poles, or 330 feet, agreeable to Mr. WILSON's example.) This done, ſet the *altimeter* perpendicular to the horizon, and ſcrew it faſt. Move the *radius*, either backwards or forwards, as occaſion may require, until the number above-mentioned be cut upon the *elevation-index* by the perpendicular line of the *altimeter*; and you will find the ſegment BC, of the baſe-line BD, to be 15 poles and 22 links, or 262 feet, cut by the inſide of the *diameter* upon the *radius*; likewiſe the perpendicular height AC to be 12 poles 4 links, or 200 feet 7 inches, cut by the *elevation-index* upon the *altimeter*. Now remove your inſtrument to the top of the hill at A, and direct the *elevation-index* downwards, until, thro' the ſights, you ſee the mark at D; having ſcrewed *it* faſt, meaſure AD with your chain (which ſuppoſe to be 16 poles 4 links, or 270 feet). Then proceed as on the other ſide of the hill, and you will find the ſegment CD, of the baſe BD, to be 9 poles 4 links,

4 links, or 151 feet. The ſum of theſe ſegments of the baſe gives 25 poles 1 link, or 413 feet, for BD, the baſe-line required.

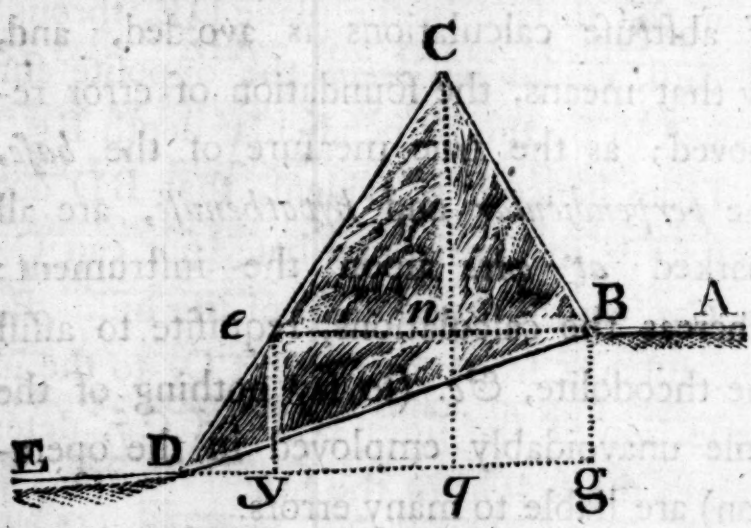
From hence it is manifeſt, that a ſeries of abſtruſe calculations is avoided, and, by that means, the foundation of error removed; as the true meaſure of the *baſe*, the *perpendicular* and *hypothenuſe*, are all marked *at once* upon the inſtrument: whereas the calculations, requiſite to aſſiſt the theodolite, *&c.* (to ſay nothing of the time unavoidably employed in the operation) are liable to many errors.

Thus having, we apprehend, clearly demonſtrated, by this comparative view, the advantage of our inſtrument over the theodolite, *&c.* both with regard to eaſe and expedition; we ſhall farther illuſtrate its uſe in meaſuring hills ſituated upon inclined baſes.

CHAP.

CHAP. VII.

Concerning the meaſurement of a mountain, or hill, when the ground on each ſide thereof is not in the ſame horizontal plane.



LET AB and DE repreſent the plane ſurface on the oppoſite ſides of the hill BCD: then will BD form the oblique, and Dg the true horizontal baſe. Now take an obſervation at B, C*n* will be the perpendicular height, and B*n* the ſegment of the horizontal baſe. On the contrary, C*q* will be the perpendicular height, and D*q* the other ſegment of the baſe, if the obſervation be made at D. We may here obſerve, that if a level from the plane ſur-

face

face A B was continued through the hill, ſuch level would appear *above* the oppoſite ſurface D E, by the perpendicular height *e* y. On the other hand, a level carried from the ſurface of the plane D E, through the hill, would fall *below* the oppoſite ſurface A B, by the perpendicular depth B g.

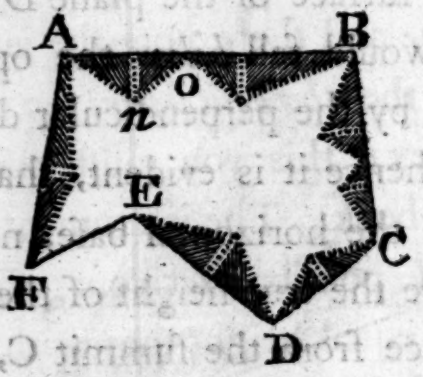
From hence it is evident, that B D does not form the horizontal baſe, nor can C *n*, or C *q*, be the true height of the hill. But the diſtance from the ſummit C, to the interſection of the lines B D and C *q*, determines the height of the hill.

Note, As the horizontal baſe D g, is to the difference B g of the heights *q* C, *n* C, ſo is the ſegment D *q* to a fourth number, which taken from the perpendicular C *q*, leaves the height required.

CHAP.

CHAP. VIII.

To meaſure the ground-plat of an irregular field, &c.



LET ABCDEF be the boundary of an irregular field; the dotted lines repreſenting the riſe and fall of the ground. Firſt, cauſe large and conſpicuous marks to be erected in all the angles of the field, at an equal diſtance from the hedge, making your obſervations without the field.

This done, remove the mark from A. Fix your inſtrument in a perpendicular poſition, in the ſame place where the mark ſtood. Set the index of the *theodolite-part* upon the 360th degree. Turn the whole about, until, through the ſights, you

you ſee the mark at F, and there ſcrew it faſt. Obſerve the bearing of the compaſs*; which muſt be entered in your field-book.

Next move the index of the *theodolite-part*, until, through the ſights, you ſee the mark at B, and there note the angle FAB, cut upon the *theodolite-part* by the nonius of its index; this you muſt alſo enter in your field-book. The inſtrument remaining in the ſame poſition, let your aſſiſtant erect a mark of equal height therewith, upon the ſummit of the firſt riſe of the ground at *n*. Raiſe the *elevation-index*, until, through the ſights, you ſee the mark at *n*, and there ſcrew it faſt. Meaſure the diſtance A*n*, and proceed to find the ſegment of the baſe, *&c.* as directed in Chap. VI. This done, remove your inſtrument to *n*. Place a mark at *o*, and depreſs the *elevation-index*, until, through the ſights, you perceive the mark at *o*. Screw *it* faſt. Then meaſure the diſtance *n o*, and proceed to

* The degrees, *&c.* to which the needle points; it being the angle that the line AF makes with the meridian.

find

find the ſegment, as before directed. Continue the proceſs in the ſame manner to B. Add the ſeveral ſegments together, and the ſum will be the true length of the baſe-line AB; which enter in your field-book. Move the mark from B, and fix your inſtrument where the mark ſtood. Let the mark be replaced at A; then ſet the index of the *theodolite-part* to the 360th degree. Move the whole about, until, through the ſights, you ſee the mark at A, and there ſcrew it faſt. Move the index of the *theodolite-part*, until, through the ſights, you ſee the mark at C; there note the angle ABC, and meaſure the diſtance BC, as before directed. Proceed in this manner to meaſure the remaining ſides and angles of the figure, and inſert them in your field-book.

It may be here neceſſary to obſerve, that the marks erected in the ſeveral angles of the field muſt be upright, and the inſtrument, upon each removal, placed on the ſpot where the mark ſtood; for without this precaution an error will ariſe.

N. B.

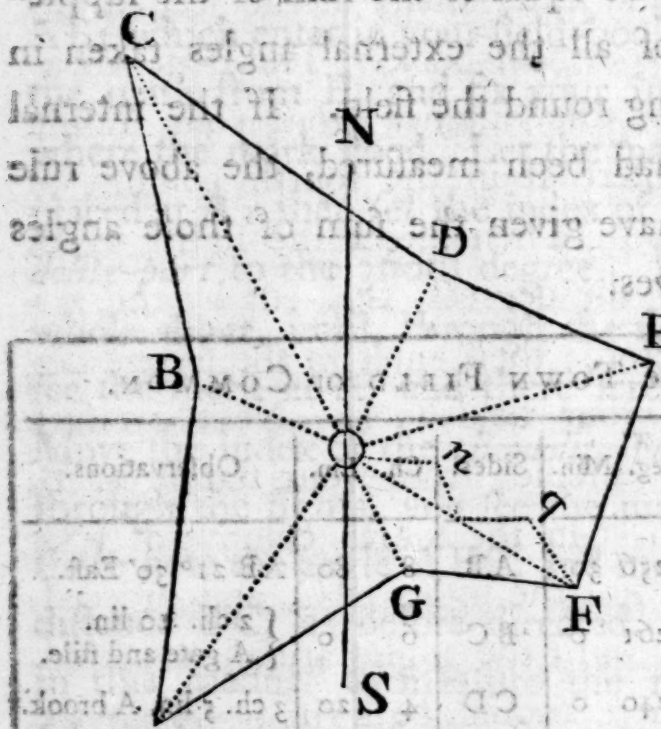
N. B. To prove the truth of your menſuration, multiply the number of ſides encloſing the field by 2; ſubtract 4 from the product, and the remainder, multiplied by 90, will be equal to the ſum of the ſupplements of all the external angles taken in meaſuring round the field. If the internal angles had been meaſured, the above rule would have given the ſum of thoſe angles themſelves.

The Town Field or Common.

Angles.	Deg.	Min.	Sides.	Ch.	Lin.	Obſervations.
FAB	256	30	AB	8	80	AB 21° 30′ Eaſt.
ABC	261	0	BC	6	0	2 ch. 10 lin. A gate and ſtile.
BCD	240	0	CD	4	20	3 ch. 5 lin. A brook.
CDE	250	0	DE	5	50	Mr. *Bottrel*'s fence.
DEF	140	0	EF	3	10	1 ch. 20 lin. A ſtile.
EFA	292	30	FA	6	30	Mr. *Jones*'s fence.

CHAP. IX.

To meaſure a field at one ſtation, and to protract the ſame.



LET ABCDEFGA repreſent an irregular field. Fix your inſtrument vertically in ſome convenient part thereof, as at O, from whence the angular points of the field are viſible. Set the *index* of the *theodolite-part* to the 360th degree. Turn the whole about, until the needle points directly

rectly to the north and ſouth of the compaſs *, and there ſcrew it faſt. Then direct the ſights to A. Note the degrees, *&c.* cut upon the *theodolite-part* by the *nonius*; and enter them in the ſecond column of your field-book. This done, meaſure O A, the diſtance from your ſtation to A: inſert it in the fourth column of your book. Then direct the ſights to B, obſerving the degrees, *&c.* cut by the *nonius* as before: theſe enter in the ſecond column of your field-book. Next meaſure O B, the diſtance from your ſtation to B, which inſert in the fourth column of your book. Point the ſights to C, and proceed, as before, until the angles are all meaſured. But if there ſhould be a riſe or fall in the land, from your ſtation to any of the angles, as in the line O *n* q F, then muſt the baſe or horizontal line be found, as directed in Chap. VIII.

* The ſights will then form the meridian line N S.

*Directions for protracting * the former field.*

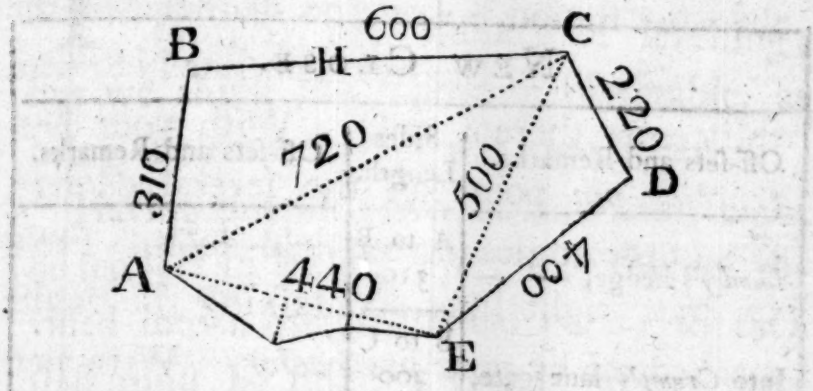
WITH your pencil draw the meridian line N S, and aſſume any point, as O, therein for your ſtation. Lay the diameter of the *protractor* upon the meridian line N S, with the center thereof at O. With your *protracting-pin* point off the ſeveral degrees, *&c.* of the angles in your field-book. From O draw right lines, containing the angles marked off by your *protractor*. With your compaſſes, from a ſcale of equal parts, ſet off (from your field-book) the diſtances O A, O B, *&c.* meaſured from your ſtation O. Join the ſeveral points, thus determined, until the whole be encloſed, and you will have the true repreſentation of the field.

* We would recommend the uſe of an entire circle for protracting with.

CHAP.

CHAP. X.

To meaſure an irregular-ſided field with the chain alone.



LET ABCDEA repreſent a level but irregular-ſided field. Erect viſible marks in all the angular points, A,B,C,D,E. This done, run your chain from A in a direct line to B, alſo from B to C, and inſert their meaſure in the middle column of your field-book. From C, run your chain directly to your firſt ſtation A, and enter its meaſure in the field-book: thus will the triangle ABC be compleated. Proceed again from A, and meaſure in a ſtraight line to E, for the crooked hedge AE: take off-ſets from the hedge in the ſeveral crooks as you go along, and inſert them in your field-book, according to the form annexed.

nexed. Then meaſure from E to C, from C to D; and laſtly from D to E: thus will the proper requiſites for protracting the field be obtained.

NEW CLOSE.

Off-ſets and Remarks.	Sides Length.	Off-ſets and Remarks.
	A to B	
Lumley's hedge, — —	310	
	B to C	
Into *Crump*'s lane gate,	200	
	600	
	C to A	
Diagonal, — — —	720	
	A to E	
	000	000. *Lloyd*'s hedge,
	200	070.
	300	020.
	440	000.
	E to C	
Diagonal, — — —	500	
	C to D	
Kerry's lane, — —	220	
	D to E	
	400	

CHAP. XI.

Of the uſe of the inſtrument in levelling.

THERE are various methods for performing the buſineſs of levelling; but we think the following preferable, as being the moſt certain and expeditious.

Having provided two ſtation-ſtaves, eight or ten feet in length, every foot thereof divided into a hundred equal parts; to each ſtaff muſt be fitted a vane *, about three inches ſquare, to ſlide with a ſcrew, in the back part, by which it may be confined at any height upon the ſtaff.

DIRECTIONS.

Place your inſtrument in a right line, joining the two ſtations to be levelled, and fix it perpendicular to the horizon. Set the *elevation-index* to the center-diviſion of the ſemi-circle, and there ſcrew it faſt. The inſtrument thus rectified, look through the ſights, and cauſe one of your aſſiſtants (pro-

* The face of the vane ſhould be painted white, and a black line drawn horizontally acroſs the middle.

vided for that purpoſe) to ſlide the vane upon the ſtaff, until the black line thereon be cut by the horizontal wires, noting the diviſions upon the ſtaff from the ground to the ſaid black line. Then remove to the other ſide of your inſtrument, and look through the ſights, cauſing your *other* aſſiſtant, at the ſame time, to move the vane upon the *other* ſtaff, until the black line and the horizontal wires coincide. Note the diviſions upon the ſtaff, from the ground to the ſaid black line. In conſequence of theſe obſervations, if the ground be level, the number of the diviſions cut by the vanes on both ſtaves will be equal. On the other hand, if thoſe numbers cut by the vanes be unequal, their difference will ſhew how much the ground declines from a true level.

Where Obſtacles intervene.

If the places to be levelled have intervening obſtacles, or ſhould be too far diſtant from each other for one obſervation, you

you muſt take as few ſtations * as poſſible, and keep a regular account of the numbers cut upon the ſtaves: let thoſe of the back ſtation be put in the firſt column, and thoſe of the fore ſtation in the third, obſerving to regiſter the number of ſtations in the intermediate column. As for example:

Back Stations.		Stations.	Forward Stations.	
0	29	1	1	32
1	78	2	2	01
1	99	3	2	95
2	21	4	2	56
6	27		8	84
			6	27
		Declivity	2	57

Thus you may determine not only the acclivity or declivity of the ground at every *ſeparate* ſtation, but alſo of *the whole* together. For the difference between the

* The forward ſtaff will become the backward ſtaff at every new obſervation.

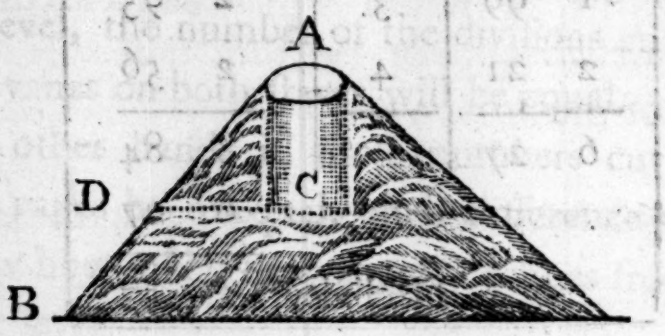
reſpective

reſpective ſum of the forward and the backward ſtations gives the aſcent or deſcent required.

Note, In levelling rivers, the firſt and laſt ſtation muſt be taken cloſe to the water's edge. But the intermediate ſtations may be taken, at pleaſure, in the meadows or fields adjoining.

CHAP. XII.

Of the uſe of the inſtrument in mineing.



To find the horizontal point for opening a drain.

FIX your inſtrument in a perpendicular poſition at A, the head of the ſhaft of the mine; erect a mark of the ſame height therewith at the foot of the hill B. Depreſs the *elevation-index*, until,

til, thro' the ſights, you ſee the mark at B, and there ſcrew it faſt. Then the depth of the ſhaft AC being known, and the *altimeter* fixed perpendicular to the horizon, move the *radius* as occaſion requires, until the aforeſaid depth AC, be cut upon the *altimeter* by the *elevation-index*. This done, you will find the true length of the drain from the bottom of the ſhaft C to D, cut by the inſide of the *diameter* on the *radius*, and alſo the diſtance from the ſhaft-head A, to the part D on the ſide of the hill, where the drain muſt be opened, cut upon the *elevation-index* by the perpendicular line of the *altimeter*.

CHAP XIII.

A certain method of finding which way the LOAD *of a mine inclines, in order to ſink a new ſhaft.*

BEING provided with two ſtation-ſtaves, about four feet high, with a ſocket in the top wherein a candle may

may be fixed; place your inſtrument directly in the center of the ſhaft, and one of the ſtaves, with a lighted candle therein, in the firſt angle or turning of the drift, at equal diſtance, as near as poſſible, from the ſides of the mine. Then lay the *index* of the *theodolite-part* to the 360th degree: turn the whole about, until the needle hangs directly over the north and ſouth points of the compaſs, and there ſcrew it faſt. This done, move the *index* of the *theodolite-part*, until, through the ſights, you ſee the lighted candle, and then obſerve the degrees, *&c.* cut upon the *theodolite-part* by the *nonius* of it's *index*, which put down in the ſecond column of your memorandum-book, according to the form annexed. With your *tape-line* meaſure the diſtance from the center of your inſtrument to the candle, and enter it in the third column of your book.

Now tranſpoſe both the inſtrument and ſtaff, fixing the former perpendicularly on the ſpot where the ſtaff was, and the latter where the inſtrument ſtood. Erect the other ſtaff in the next angle of the drift, in the

manner

manner as above directed. Lay the index of the *theodolite-part* as before, turning the whole about, until you ſee the candle at the firſt ſtation; and there ſcrew it faſt. Move the *index* of the *theodolite-part*, until you ſee the candle in the ſecond ſtation; obſerve the degrees cut by the *nonius* of its *index*, and enter it in the ſecond column of your book. Meaſure the diſtance from your inſtrument to the ſecond candle, which enter in the third column of your book.

Now change the ſtations of the inſtrument and ſtaves: the former muſt be fixed in the ſpot where the ſecond candle ſtood, and that muſt be removed to the next angle of the drift, while the firſt muſt be placed where the inſtrument was laſt erected. This done, proceed as before directed, until the whole be finiſhed. The meaſurement *in the mine* being taken, you muſt take the ſame *above-ground* in the following manner.

Cover the mouth of the ſhaft with boards, and place your inſtrument perpendicularly in the center thereof. Then the *index* of the *theodolite-*

theodolite-part being fixed to the 360th degree, turn the whole about, until the needle ſtands directly over the north and ſouth points of the compaſs, and there confine it. Move the *index* of the *theodolite-part* to the number of degrees, &c. of the firſt ſtation taken in the mine, and entered in your memorandum-book. This done, and the inſtrument remaining in the ſame poſition, let your aſſiſtant erect a mark of equal height therewith, in a direct line with the ſights, about a yard farther than the diſtance of the *firſt meaſure* in your book. Then raiſe or depreſs the *elevation-index*, until, thro' the ſights, you ſee the ſaid mark; and having ſcrewed it faſt, (the *altimeter* at the ſame time being confined in a perpendicular direction) move the *radius* until the ſaid *firſt meaſure* be cut thereon by the inſide of the *diameter*. You will then find the diſtance to be meaſured upon the ſurface of the land, from the inſtrument to the next ſtation, cut upon the *elevation-index* by the perpendicular line of the *altimeter*, which enter in the fourth column of your

your book. You will find alſo the perpendicular aſcent or deſcent of the ground in that diſtance, cut upon the *altimeter* by the *elevation-index*; and this muſt be entered, if an acclivity, in the fifth; if a declivity, in the ſixth column of your book. Then with your *tape-line* meaſure the diſtance as inſerted in the fourth column of your book, *viz.* from your ſtation towards the mark. At the termination of this diſtance fix your inſtrument.

Let your aſſiſtant remove the firſt mark to the ſpot on which the inſtrument ſtood. Set the *index* of the *theodolite-part* to the 360th degree. Turn the whole about, until you ſee the aforeſaid mark in its new ſtation, and there ſcrew it faſt. Move the *index* of the *theodolite-part* to the number of degrees, *&c.* inſerted in your book at the ſecond ſtation under ground. Cauſe your aſſiſtant to erect another mark, about a yard beyond the diſtance entered in your book at the ſecond ſtation, as before directed. Raiſe or depreſs the *elevation-index*, until, thro' the ſights, you ſee the ſaid mark; there ſcrew it faſt.

faſt. Proceed now in all reſpects as before laid down, until the whole be accompliſhed.

Then the difference between the reſpective ſums of the aſcents and deſcents (being added to, or ſubtracted from, the depth of the main ſhaft) gives the depth of the ſhaft required, according as the ſum of the aſcents was greater or leſs than that of the deſcents: the ſpot, therefore, where the laſt meaſurement terminated, will be the direct place where the new ſhaft muſt be opened.

FORM *of a* MEMORANDUM-BOOK.

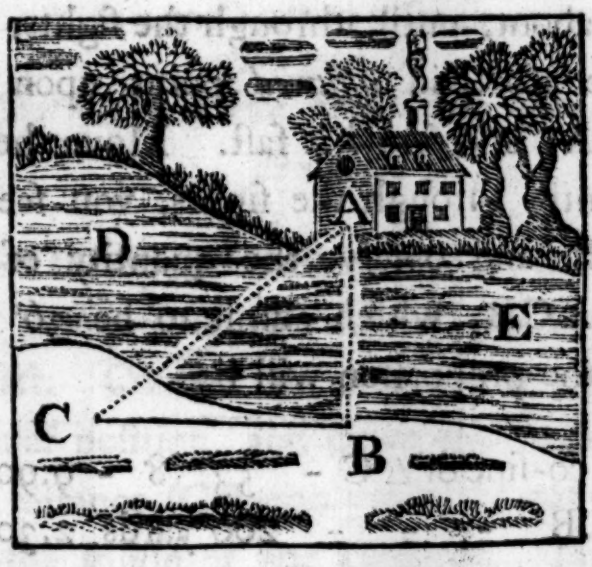
First Station directly in the Center of the Shaft, 70 Feet deep.

Number of Stations.	Angles at each Station.	Diſtances between the Stations meaſured in the Mine.	Dif. above ground, correſponding with thoſe in the mine.	Acclivities of the Surface.	Declivities of the Surface.	Depth of the Shaft at every diſtance.	Obſervations.

CHAP. XIV.

HAVING already deſcribed the uſes of our inſtrument, (with regard to the meaſuring of ſtanding timber, ſurveying, *&c.*) as far as the nature of the preſent work would admit; yet, perhaps, it may not be improper to ſubjoin ſome entertaining examples, which may farther ſerve to evince it's utility in performing trigonometrical operations.

To meaſure the breadth of a river.



Let D E repreſent a river, whoſe breadth is required. Place your inſtrument at any

convenient point, as at B. Lay the *index* of the *theodolite-part* to the 360th degree. Turn the inſtrument about, until, through the ſights, you ſee ſome particular *aſſumed* point upon the object A; and ſcrew it faſt. This done, move the *index* to the 270th degree *. Cauſe your aſſiſtant to erect a mark, in a right line with the ſights, at any diſtance, as at C. Tranſpoſe both the inſtrument and mark. Meaſure the diſtance C B, equal to 200 yards.

Now lay the *index* of the *theodolite-part* to the 360th degree, as before. Turn the whole about, until, through the ſights, you ſee the aforeſaid *aſſumed* point upon the object A; and ſcrew it faſt. Move the *index*, until, through the ſights, you ſee the mark B, and obſerve the quantity of the angle A C B; which admit to be 36° 52′. Then the proportion will be

As the co-ſine of ∠ C -	53° 8 -	9.90311
Is to C B - - -	200 yards	2.30103
So is ſine of ∠ C - -	36° 52′	9.77812
To B A - - -	150 yards	2.17604

* It being at right angles with the 360th degree.

Note,

Note, If, in the foregoing proceſs, the *index* of the *theodolite-part* were laid to the 90th degree, inſtead of the 270th, turn the inſtrument about, at your ſtation C, until you ſee the mark B. Then take the angle B C A, and proceed, in all other reſpects, as above directed.

Note alſo, If you cannot fix your inſtrument cloſe to the river, you ſhould meaſure the diſtance from your ſtation B to the edge of the water; which, ſubtracted from the whole line B A, gives the true breadth of the river required.

To work the above proportion upon the inſtrument.

Set the *elevation-index* to 36° 52′ * upon the *ſemi-cirle* of the inſtrument, and ſcrew it faſt. Confine the *altimeter* in a perpendicular poſition, and move the *radius* until the diſtance (C B 200 yards) be cut upon it by the inſide of the *diameter.* Then you

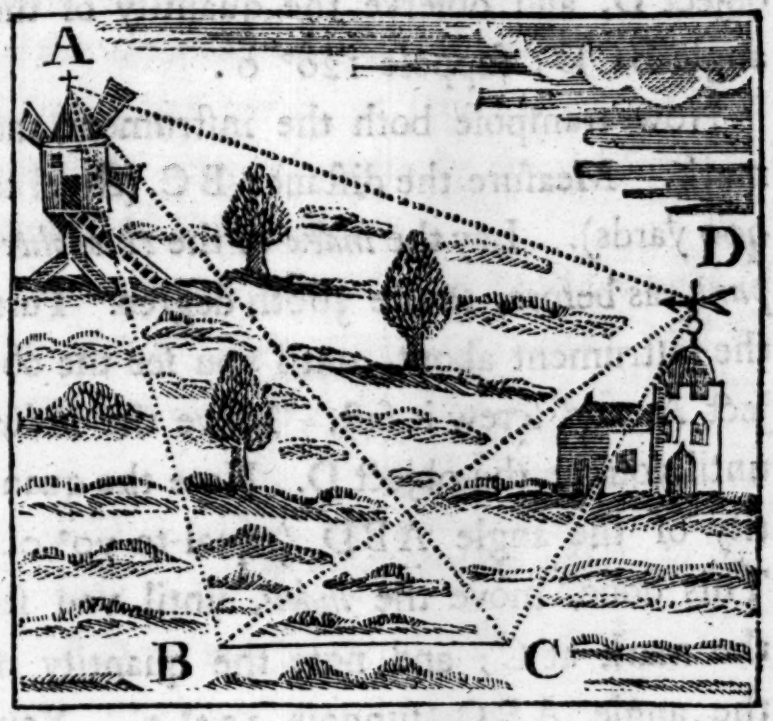
* The quantity of the angle cut by the *nonius* on the *theodolite-part.*

will find the breadth of the river (BA 150 yards) cut upon the *altimeter* by the *elevation-index*; and alſo the diſtance (CA 250 yards) cut upon the *elevation-index* by the perpendicular line of the *altimeter*.

CHAP.

CHAP. XV.

To meaſure the diſtance between two remote objects.



SUPPOSE A and D to repreſent two remote objects, whoſe diſtance from the ſtations B, C, and likewiſe from each other, is required.

Place your inſtrument at C, and a mark at B. Lay the *index* of the *theodolite-part* to the 360th degree. Turn the inſtrument

about, until you ſee the mark at B, and ſcrew it faſt. Then move the *index*, until you ſee the object A. Obſerve the quantity of the angle BCA; which admit to be 51° 26′. Move the *index* until you ſee the object D, and obſerve the quantity of the angle BCD; ſuppoſe 120° 0′.

Now tranſpoſe both the inſtrument and mark. Meaſure the diſtance BC (equal to 900 yards). Lay the *index* of the *theodolite-part*, as before, to the 360th degree. Turn the inſtrument about, until you ſee the object A, and ſcrew it faſt. Move the *index*, until you ſee the object D. Note the quantity of the angle ABD (equal to 70° 0′.) This done, move the *index*, until you ſee the mark at C; and note the quantity of the angle ABC, ſuppoſe 105° 0′. Your obſervations thus compleated, proceed

To work the ſeveral propertions upon the inſtrument.

Set the angle ABC (105°) on the ſmall ſemi-circle of the *altimeter*, to the *nonius* upon the *radius*, and ſcrew it faſt. Then ſet the *nonius* of the *elevation-index* to the angle

angle BCA (51° 26′) upon the ſemi-circle of the inſtrument. This done, move the *radius*, until the diſtance CB (900 yards) be cut thereon by the inſide of the *diameter*. You will then find the diſtance BA = 1760 yards, or one mile, cut upon the *altimeter* by the *elevation-index*; and alſo the diſtance CA = 2171 yards, or 1 m. 1 f. 34 $\frac{27}{44}$ p. cut upon the *elevation-index* by the perpendicular line of the *altimeter*.

By a ſimilar proceſs the meaſurement of the ſides of the remaining angles will be found, as follows;

	Yards.		M.	F.	P.
BD =	1853,	or	1	0	16 $\frac{10}{11}$.
CD =	1223,	or	0	5	22 $\frac{4}{11}$.
AD =	2073,	or	1	1	16 $\frac{10}{11}$.

It may here be neceſſary to remark that, in the application of our inſtrument to meaſuring diſtant objects, we have been led to the following conſiderations.

If an angle be taken *out* of the plane of of the horizon, ſuch angle is leſs than the horizontal one ſubtending the ſame, or

equal, ſide. From an obſervation, therefore, taken *out* of the horizontal plane, no true plan can be formed, nor until it be reduced thereto; which may be effected thus.

Set the *nonius* of the *elevation-index* upon the ſemi-circle of the inſtrument, to the degrees, *&c.* in the angle made by the interſection of the plane of the obſerved angle, and the plane of the horizon. There ſcrew it faſt. Confine the *altimeter* in a perpendicular poſition. Then move the *radius*, until the baſe-line of the obſerved angle be cut upon the *elevation-index* by the perpendicular line of the *altimeter*. This done, you will find the correſponding horizontal baſe-line cut by the inſide of the *diameter* upon the *radius*.

Now ſet the degrees, *&c.* contained between the baſe and ſide ſubtended by the obſerved angle, upon the ſmall ſemi-circle of the *altimeter*, to the *nonius* of the *radius*, and ſcrew it faſt. Then ſet the *elevation-index* to the number upon the *altimeter*, *viz.* the length of the ſide including the obſerved angle,

angle, upon the *altimeter*. This done, you will find the correſponding horizontal angle upon the ſemi-circle of the inſtrument cut by the *nonius* of the *elevation-index*.

Note, If the different objects form different angles of inclination to the plane of the horizon, they muſt be conſidered reſpectively.

It is requiſite to obſerve, that, in very remote diſtances, the horizontal lines ought to be conſidered as tangents to an arc of the earth's circumference. To find the angle, at the earth's center, ſubtending the ſaid tangent, we have the following rule:

As the ſemi-diameter of the earth is to the horizontal diſtance meaſured; ſo is the *radius* (90°) to the tangent of the arc required.

Now to find the length of the ſaid arc, multiply * the earth's circumference by the quantity of the angle ſubtending the tangent: divide the product by 360°; and the

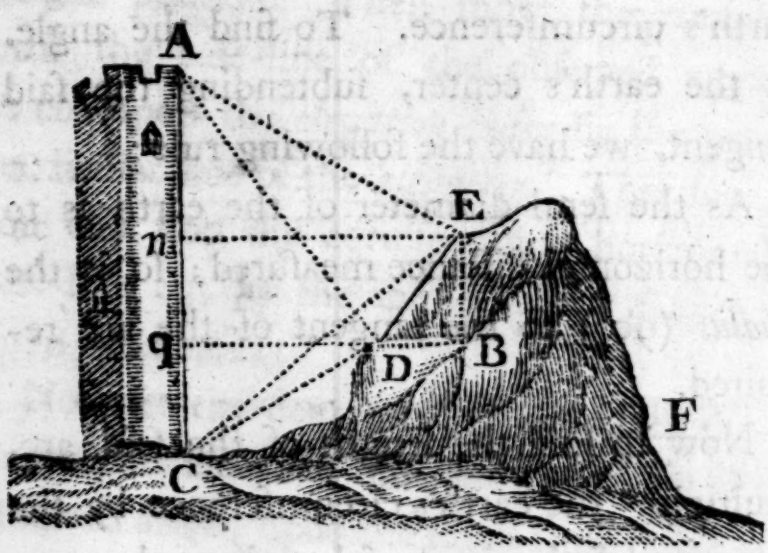
* In this operation your multiplier and diviſor muſt always be of one and the ſame denomination; whether degrees, minutes, &c.

quotient

quotient will be the length of the arc; which is the true line to be delineated.

CHAP. XVI.

To find the height and diſtance of any tower or battery, it's elevation or depreſſion above or below the horizon, when the ground between the ſtations is not in the ſame horizontal plane.



LET AC repreſent a tower, and CDEF an adjacent hill. From the ſtations D and E it is required to determine the horizontal diſtances D*q*, E*n*; the extreme diſtances

diſtances DA, DC, EA, EC; altitudes *q*A, *n*A; and the height of the tower AC.

Place your inſtrument at D, and meaſure the angles *q*DC, *q*DA. Turn your inſtrument about, and meaſure the angle BDE. The ſum of this angle, and the former *q*DA, being ſubtracted from 180°, leaves the angle ADE.

This done, tranſpoſe the inſtrument to E. Meaſure the diſtance DE, and take the angles of depreſſion *n*EC, *n*ED, and angle of elevation *n*EA. The ſum of the angles *n*ED, *n*EA, gives the angle DEA; to which add the angle ADE, and ſubtract the ſum from 180°, the remainder will be the quantity of the angle DAE.

From theſe obſervations the ſeveral parts, as required in the above problem, may be found by the following calculation.

1.

As the ſine of	-	∠ DAE
Is to diſtance	-	- DE
So is ſine of	-	∠ DEA
To the viſual line	-	DA

2. As

2.

As radius
Is to - - - DA
So is ſine of - ∠ *q*DA
To - - *q*A
And ſo is co-ſine - ∠ *q*DA
To - - *q*D

3.

As co-ſine - ∠ *q*DC
Is to - - - *q*D
So is ſine - - ∠ *q*DC
To - - *q*C
And ſo is radius
To diſtance - - - CD

4.

As radius
Is to diſtance - DE
So is co-ſine - ∠ BDE
To - - DB
And ſo is ſine - - ∠ BDE
To - - EB

5.

As co-ſine - - ∠ *n*EC
Is to - - *n*E
So is radius
To viſual diſtance - - CE

Thus

Thus the diſtance of any propoſed point of a tower, or battery, either above or below the horizon, may be found by directing the obſervations to that particular, propoſed, point.

Note, The above proportions may be performed upon the inſtrument, according to the directions in the preceding chapter.

CHAP. XVII.

To meaſure the front of a houſe.

THE HEIGHT.

PLACE your inſtrument towards the left ſide of the houſe, at right angles with the corner. Confine the *altimeter* in a perpendicular poſition. Meaſure your diſtance from the houſe to the *axis* of the inſtrument. Move the *radius*, until that diſtance be cut thereon by the inſide of the *diameter*. This done, depreſs the *elevation-index*, until, through the ſights, you ſee the bottom of the houſe: there note the number cut upon the *altimeter* by the ſaid *index*. Then raiſe the *elevation-index* until you ſee the top of the houſe, and there note the

the number cut upon the *altimeter* by the *index*: the ſum of theſe numbers is the *height* of the houſe required.

THE BREADTH.

Lay the *horizontal-index* upon the firſt diviſion of the moveable limb of the *ſliding-piece*. Obſerve, through the ſights, that the left edge of the front be cut by the *perpendicular wires*. Set the moveable limb of the *ſliding-piece* parallel to the front. This done, move the *index* alone, until you ſee the edge of the houſe, on the right hand, cut alſo by the *perpendicular wires*: you will then find the required breadth expreſſed upon the moveable limb of the *ſliding-piece* by the *horizontal-index*.

In like manner the height and breadth of a window, in the front or ſide of a houſe, may be eaſily obtained.

*** To theſe examples already given, many others, we apprehend, will readily occur to the reader; whereby the extenſive uſe of this inſtrument might be farther illuſtrated.

TABLES

APPENDIX.

THE principles of geometry, confirmed by obſervation, ſhew, that angles either acute or obtuſe, taken by the inſtrument, when *out* of the horizontal plane, are very different from their correſponding or projected angles *upon* the plane of the horizon; ariſing from the different ſituations of the obſerved objects: *viz.*

Firſt, If the objects be elevated above, or depreſſed below, the horizon, the obſerved angle will be *leſs* than its projected angle upon the horizontal plane.

Secondly, If one of the objects be elevated or depreſſed, and the other *in* the plane of the horizon, the obſerved angle will be *greater* than its projected angle upon the horizontal plane; except the obſerved angle

be 90° 00′ : for, in ſuch caſe, the obſerved and projected angles will be equal.

Thirdly, If one object be elevated and the other depreſſed from the horizon, the obſerved angle will be greater, or leſs, than its projected angle upon the horizontal plane, according to the difference of the angles obſerved upon the ſemi-circle of the inſtrument, and ſmall circular arches.

1. If the angle, obſerved upon the ſemi-circle of the inſtrument, be leſs than the angle obſerved upon the ſmall circular arches, the obſerved angle upon the ſmall quadrant (fixed for that purpoſe upon the horizontal index) will be greater than its projected angle upon the horizontal plane.

2. If the angle, obſerved upon the ſemi-circle of the inſtrument, be greater than the angle obſerved upon the ſmall circular arches, the obſerved angle upon the ſmall quadrant will be leſs than its projected angle upon the horizontal plane.

N. B. If the angles obſerved upon the ſemi-circle of the inſtrument and ſmall circular

cular arches be alike (or the ſame) the angle obſerved upon the ſmall quadrant, and its projected angle upon the plane of the horizon, will alſo be alike, or the ſame.

In conſequence of the addition of a *ſmall quadrant* upon the *horizontal index*, (ſee Deſcription, page 14*) it will be neceſſary to give a rule for reſolving the following

PROBLEM.

The meaſure of an angle being taken either above or below the horizon, to find the quantity of the correſponding or projected angle upon the horizontal plane.

The RULE.

The altimeter being in a vertical poſition, ſet the nonius of the *elevation index* to the degrees, *&c.* contained between the plane of the obſerved angle and the plane of the horizon, and there ſcrew it faſt. Move the *horizontal index*, until the angle obſerved upon the limb of the theodolite be cut upon the *ſmall quadrant* by its nonius.

Note the number cut upon the *moveable limb* of the ſliding-piece by the *horizontal index*. This done, ſet the *elevation index* to 00 degrees, and ſcrew it faſt. Set the *horizontal index* to the ſame number (as above noted) upon the moveable limb of the ſliding-piece. You will then find the correſponding angle cut by its nonius upon the *quadrant*.

To meaſure an angle which has different inclinations to the plane of the horizon.

RULE.

Lay the *horizontal index* to the firſt diviſion on the *moveable limb* of the ſliding-piece. Turn the inſtrument about, until you ſee the object towards the left hand. Move the *horizontal index*, until you ſee the other object towards the right hand. Obſerve the number cut upon the *moveable limb* of the ſliding-piece by the ſaid *index*, and alſo the degrees, *&c.* upon the ſmall *circular arches*.

This

This done, the obſerved angle may be reduced to the plane of the horizon by the following

RULE.

Set the *elevation index* to the degrees, *&c.* obſerved upon the ſmall *circular arches.* Note the number cut upon the *radius.* Move the *radius* until the number obſerved upon the *moveable limb* of the ſliding-piece be cut upon the *elevation index* by the perpendicular line of the *altimeter*, and note the number then cut upon the *radius.* Now ſet the *elevation index* and ſmall *circular arches* to oo degrees, and draw the *radius* to the number firſt noted thereon. Lay the *horizontal index* to the ſame number upon the *moveable limb* of the ſliding-piece as was obſerved the ſecond time upon the *radius:* then will the correſponding horizontal angle be pointed out by the nonius upon the limb of the *quadrant.*

At page 18, add the following method for ſetting the *altimeter* in the ſame direction with the tree:

Before

Before the horizontal diſtance is meaſured with the tape-line, &c. take the inſtrument in your hand, from your ſtation, either to the right or left ſide of the tree, as may be moſt acceſſible. Hold it ſide-ways, at any convenient diſtance therefrom, in a vertical poſition, obſerving to keep the diameter of the inſtrument always on the ſide next your ſtation. Then move the *altimeter*, until you obſerve it form the ſame angle with the *radius*, as the tree forms with the horizon; or until the lines of columniation coincide.

At page 19—— When the *radius* muſt be moved to cut the diſtance meaſured from the tree, it is proper to obſerve, that if you cannot fix your ſtation within the diſtance of 20 feet from the tree (it being the number of equal diviſions upon the *radius*,) or if the length thereof ſhould extend above 40 feet (the number of equal diviſions upon the *altimeter*,) in ſuch caſe you muſt move the radius to $\frac{1}{2}$, $\frac{1}{3}$, or $\frac{1}{4}$ of the diſtance meaſured. Then the height and diameter of the tree will accordingly be

be twice, thrice, or four times as much as the height and diameter meaſured upon the inſtrument. Otherwiſe you may call the diviſions by any other denomination, as yards, poles, furlongs, miles, *&c.* agreeable to the denomination in which you take your diſtance.

To adjuſt the inſtrument.

RULE.

The inſtrument being fixed upon the ſtaff, ſlacken the ſcrew, in the parallel plates, on the ſide elevated; at the ſame time ſtreighten the oppoſite ſcrew. Proceed thus until the whole inſtrument may be turned round upon the ſtaff without altering the due poſition of the bubble in the ſpirit-level. In the ſame manner the *dendrometer* may be ſet vertical to the plane of the horizon by the adjuſting ſcrew, in the part by which it is fixed to the *theodolite*.

N. B. If the plane of the limb of the *theodolite* be ſet parallel to the plane of the

the horizon, and the *dendrometer* ſet exactly vertical, ſo that it may be turned round without altering the true poſition of the plummet; it will then follow, that if the limb of the *theodolite* be exactly horizontal, the *dendrometer* will be exactly vertical.

E R R A T A.

		T.	F.	I.
At page 17.	True Solidity	7	26	11 $\frac{3}{4}$
	Com. Solidity	5	44	6 $\frac{1}{4}$

TABLES